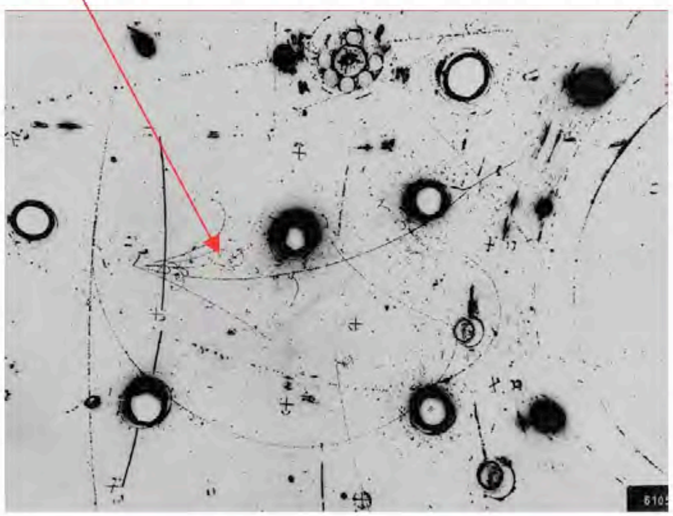
Liquid Argon presents prospect of continuously live Imaging Calorimeter

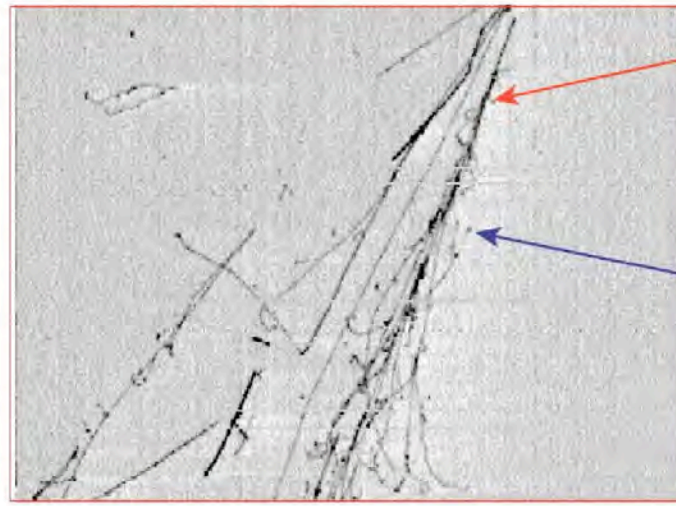
Thirty years of progress........

LAr is a cheap liquid (≈1CHF/litre), vastly produced by industry

Bubble diameter ≈ 3 mm (diffraction limited)

Gargamelle bubble chamber ICARUS electronic chamber





"Bubble" size ≈ 3 x 3 x 0.2 mm^3

Energy deposition measured for each point

40 cm

Drift

Medium	*Heavy freon*	
Sensitive mass	3.0	ton
Density	1.5	g/cm^3
Radiation length	11.0	cm
Collision length	49.5	cm
dE/dx	2.3	MeV/cm

Medium	*Liquid Argon*	
Sensitive mass	Many ktons	
Density	1.4	g/cm^3
Radiation length	14.0	cm
Collision length	54.8	cm
dE/dx	2.1	MeV/cm

C. Rubbia

Some LArTPC Technical Issues for Neutrino Detectors

Argon Purity

- **From atmosphere to purity without evacuation**
- How to remove impurities from Argon (filter gas as well as liquid?)
- What impurities matter and how to measure drift lifetime
- What are the sources of contamination and how to avoid/remove them without pumping (vessel, plastics=> surface physics)

Vessel Design

- Design, **(Underground) Construction**, Safety
- Cryogenics (cooling system and insulation)
- Thermodynamics (argon temperature and flow distribution)

Detector Design

- HV system
- Mechanical reliability - **TPC constructed in situ or externally**
- Constraints from electronics (eg readout only at top?)
- Light collection scheme; (for \`triggering' and pattern recognition)

Electronics & DAQ

- Amplifiers, multiplexing, digitizers - **in cryostat?** Feedthroughs
- Signal/noise (large capacitance) and constraints on TPC design
- Zero suppression, signal processing, local event recognition capability, **100% livetime (not just beam spill)**

Simulation & Reconstruction

- Real and simulated signals on wires; develop signal processing
- Event generation in argon
- Vertex and pattern recognition; cosmic ray rejection; event reconstruction

Test Stand Work at Fermilab

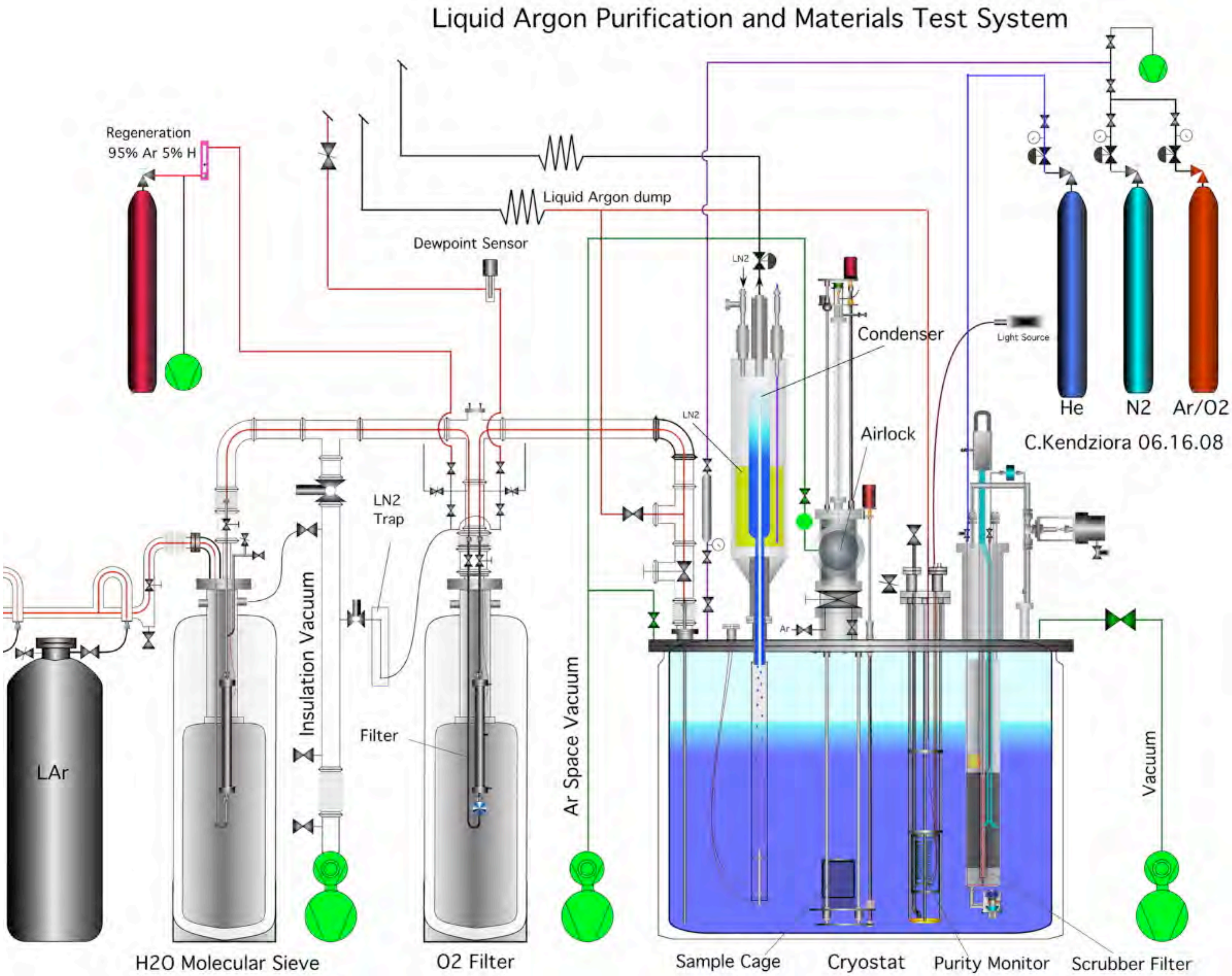
Materials Test System (MTS) - Luke
TPC for electronics development - Bo
Bell-jar for photo-cathode and light-fiber testing

Tests performed for atmosphere to purity without evacuation

- Demonstration of Argon Piston (purge to few ppm)
- Demonstration of Oxygen to few ppb and water to few ppm

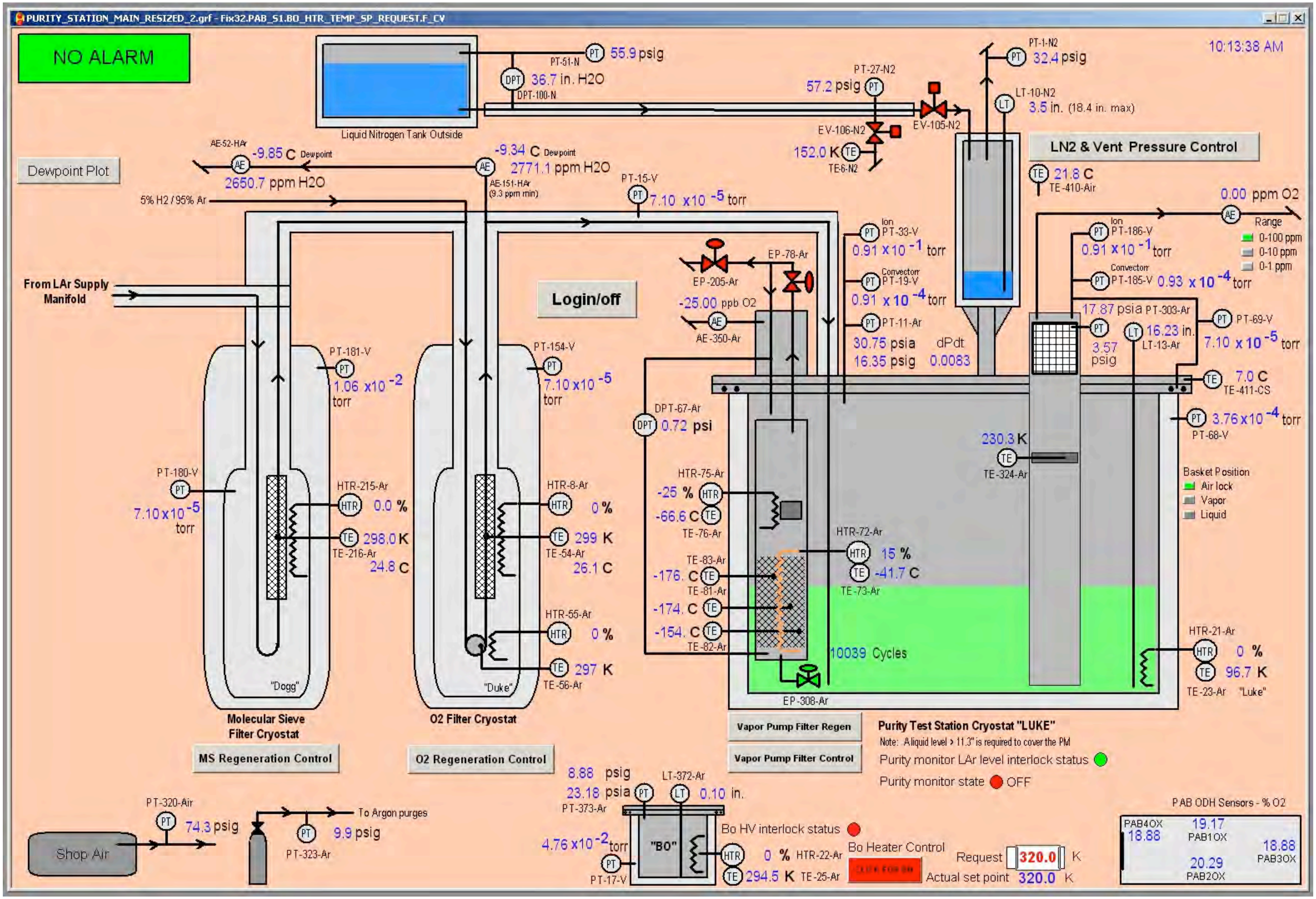
Infrastructure

- Single Pass clean Argon Source with Oxygen and H_2O filters.
- Home-made Filters for above that can be regenerated in-situ
- Internal Filter Pump
- Controls System
- Purity Monitor DAQ
- Fermilab versions of ICARUS \`purity monitor' and readout electronics
- Nitrogen concentration measurement (at the 0.2 ppm)

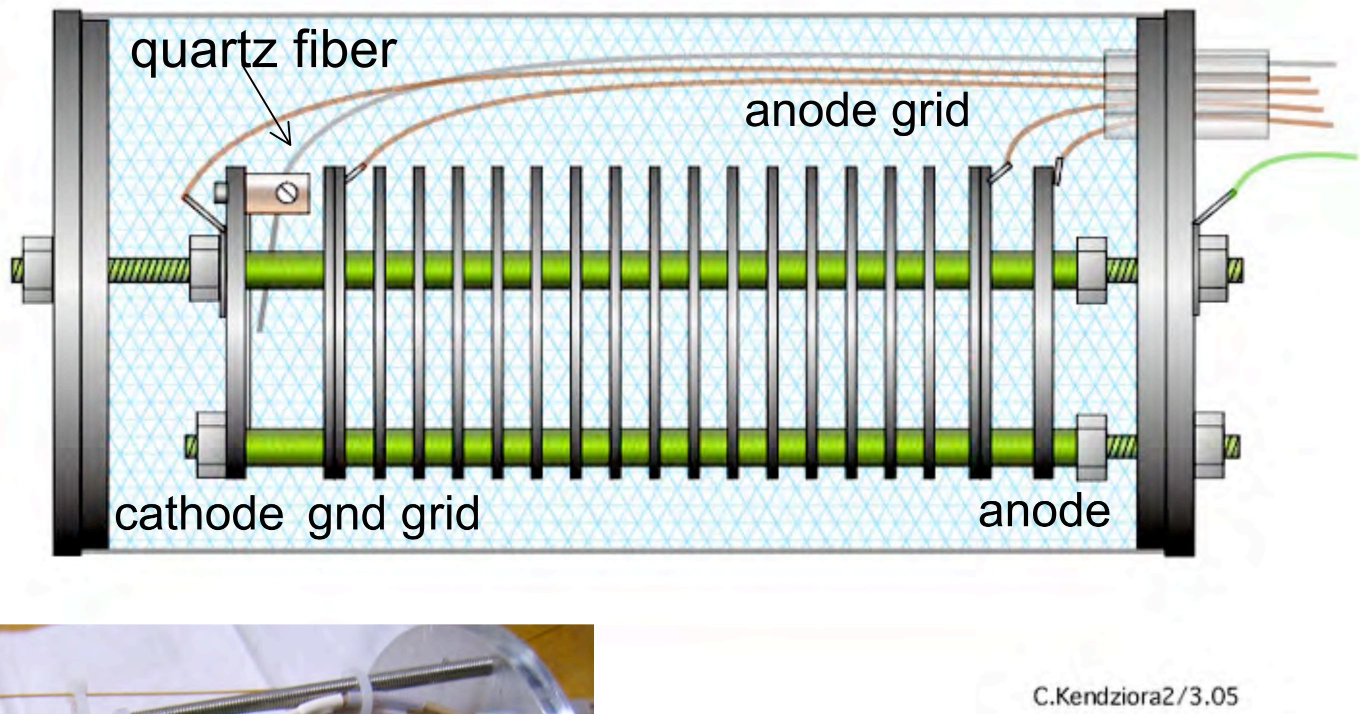


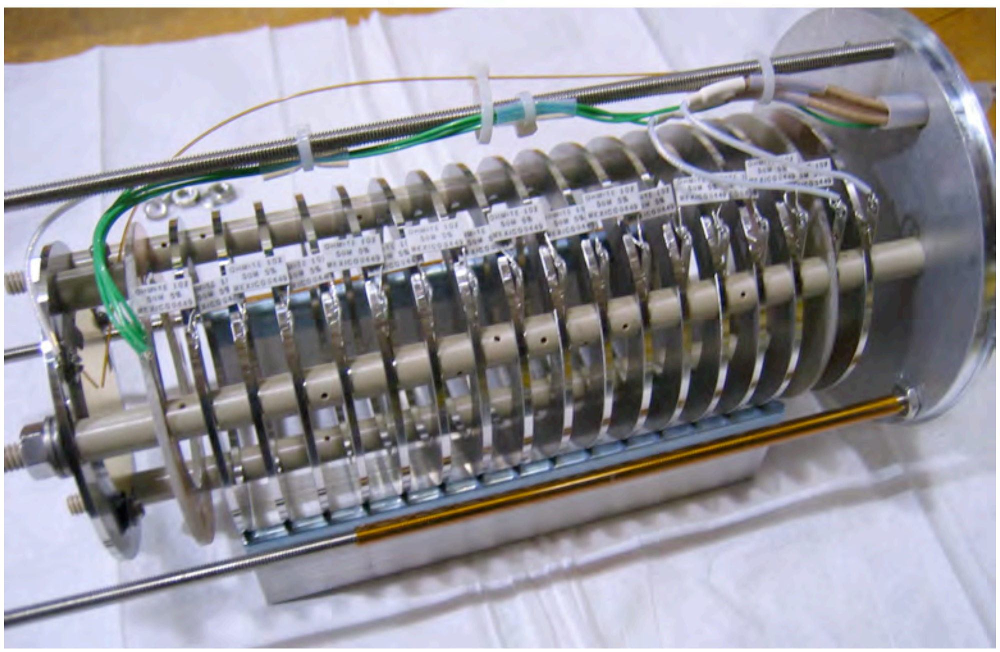
Liquid Argon Purification and Materials Test System
Regeneration
95% Ar 5% H
Liquid Argon dump
Dewpoint Sensor
LN2
Condenser
Light Source
Airlock
LN2
Trap
Insulation Vacuum
Filter
Ar Space Vacuum
Vacuum
He
N2
Ar/O2
C.Kendziora 06.16.08
LAr
Ar
H2O Molecular Sieve
O2 Filter
Sample Cage
Cryostat
Purity Monitor
Scrubber Filter


Argon
Argon
Cu Filter (O2)
Materials
Test System
Zeolite Filter (H2O)
TPC & Electronics
Test System
Argon Supply


PURITY_STATION_MAIN_RESIZED_2.grf - Fix32.PAB_51.B0_HTR_TEMP_SP_REQUEST.F_CV
NO ALARM
Liquid Nitrogen Tank Outside
PT-51-N 55.9 psig
DPT 36.7 in. H2O
DPT-100-N
PT-27-N2
57.2 psig
PT-1-N2 32.4 psig
LT-10-N2 3.5 in. (18.4 in. max)
10:13:38 AM
EV-106-N2
EV-105-N2
152.0 K TE-6-N2
LN2 & Vent Pressure Control
21.8 C TE-410-Air
Dewpoint Plot
AE-52-HAr -9.85 C Dewpoint
2650.7 ppm H2O
-9.34 C Dewpoint
2771.1 ppm H2O
AE-151-HAr (9.3 ppm min)
5% H2 / 95% Ar
PT-15-V 7.10 x10 -5 torr
0.00 ppm O2
Range
0-100 ppm
0-10 ppm
0-1 ppm
Ion PT-33-V 0.91 x 10 -1 torr
Convector PT-19-V 0.91 x 10 -4 torr
PT-11-Ar
30.75 psia
16.35 psig
dPdt 0.0083
Ion PT-186-V 0.91 x 10 -1 torr
Convector PT-185-V 0.93 x 10 -4 torr
17.87 psia PT-303-Ar
3.57 psig
16.23 in. LT-13-Ar
PT-69-V 7.10 x 10 -5 torr
7.0 C TE-411-CS
3.76x10 -4 torr PT-68-V
From LAr Supply Manifold
Login/off
EP-205-Ar
EP-78-Ar
-25.00 ppb O2
AE-350-Ar
PT-181-V 1.06 x10 -2 torr
PT-154-V 7.10x10 -5 torr
DPT-67-Ar 0.72 psi
PT-180-V 7.10x10 -5 torr
HTR-215-Ar 0.0 %
298.0 K TE-216-Ar
24.8 C
HTR-8-Ar 0 %
299 K TE-54-Ar
26.1 C
HTR-55-Ar 0 %
297 K TE-56-Ar
"Dogg"
"Duke"
HTR-75-Ar -25 %
-66.6 C TE-76-Ar
TE-83-Ar -176. C
TE-81-Ar -174. C
-154. C TE-82-Ar
HTR-72-Ar 15 %
-41.7 C TE-73-Ar
230.3 K TE-324-Ar
Basket Position
Air lock
Vapor
Liquid
10039 Cycles
HTR-21-Ar 0 %
96.7 K TE-23-Ar "Luke"
EP-308-Ar
Molecular Sieve Filter Cryostat
O2 Filter Cryostat
MS Regeneration Control
O2 Regeneration Control
Vapor Pump Filter Regen
Vapor Pump Filter Control
Purity Test Station Cryostat "LUKE"
Note: A liquid level > 11.3" is required to cover the PM
Purity monitor LAr level interlock status
Purity monitor state OFF
8.88 psig
23.18 psia PT-373-Ar
LT-372-Ar 0.10 in.
4.76 x10 -2 torr PT-17-V
"BO"
Bo HV interlock status
0 % HTR-22-Ar
294.5 K TE-25-Ar
Bo Heater Control
Request 320.0 K
Actual set point 320.0 K
PAB ODH Sensors - % O2
PAB4OX 18.88
PAB1OX 19.17
PAB3OX 18.88
PAB2OX 20.29
PT-320-Air 74.3 psig
Shop Air
To Argon purges
PT-323-Ar 9.9 psig

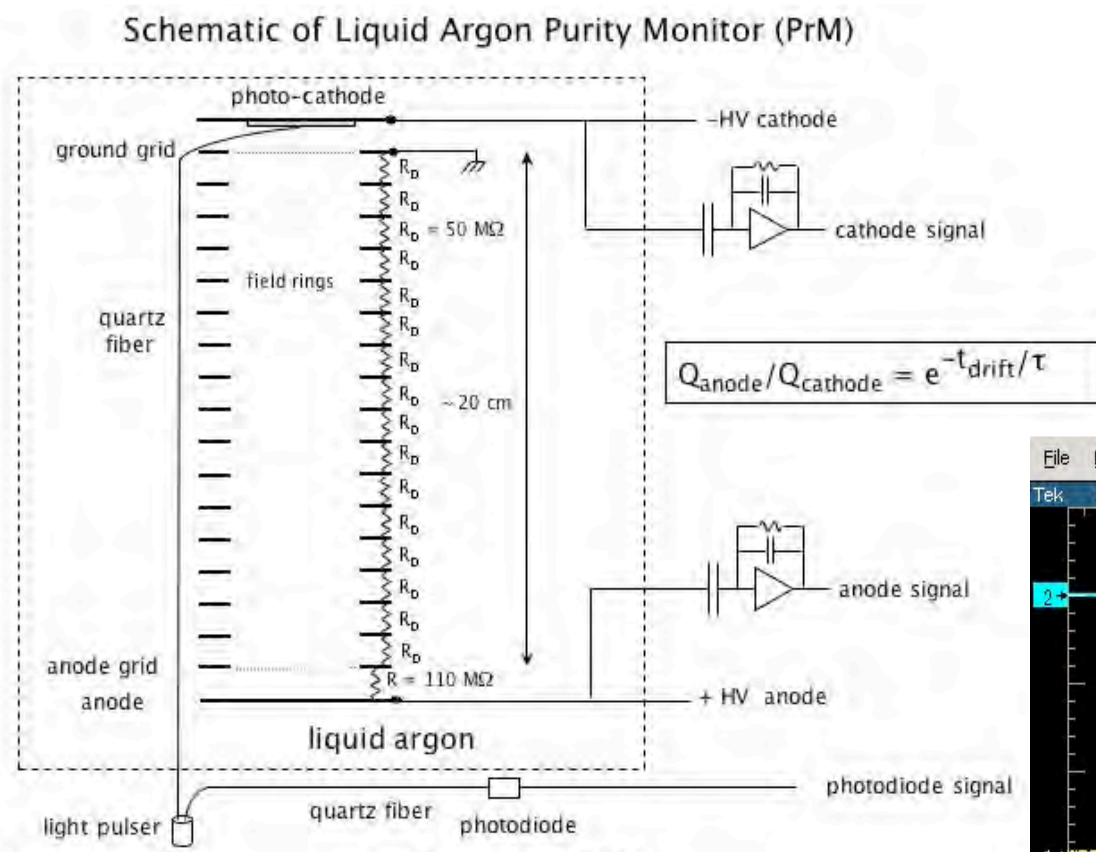
PrM drawing



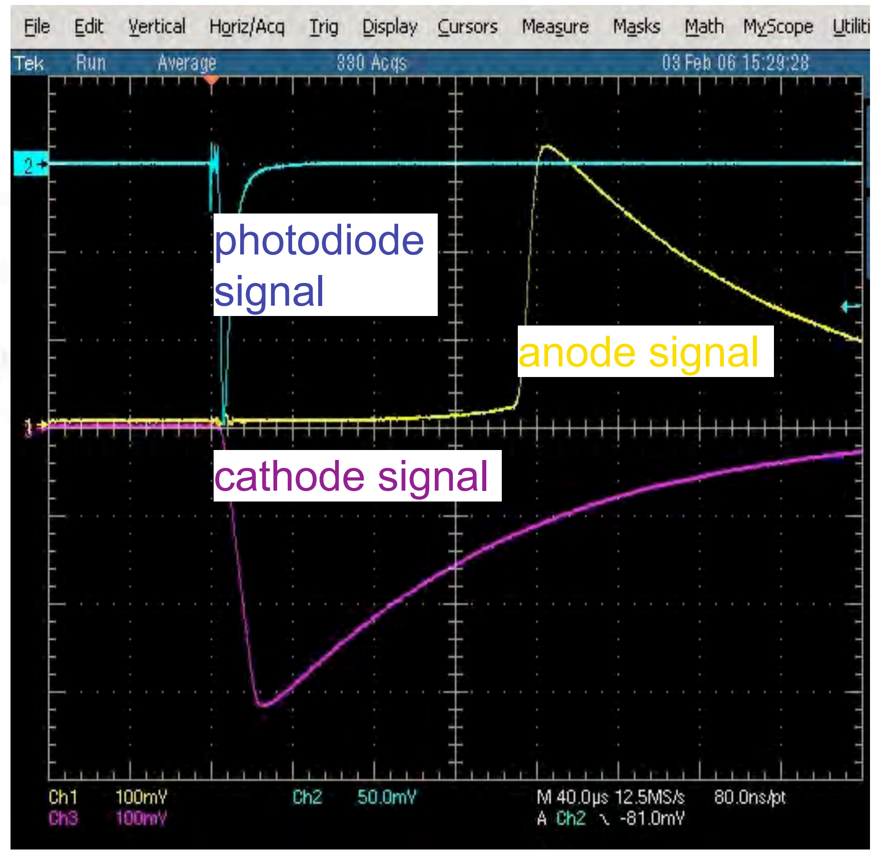


PrM photograph

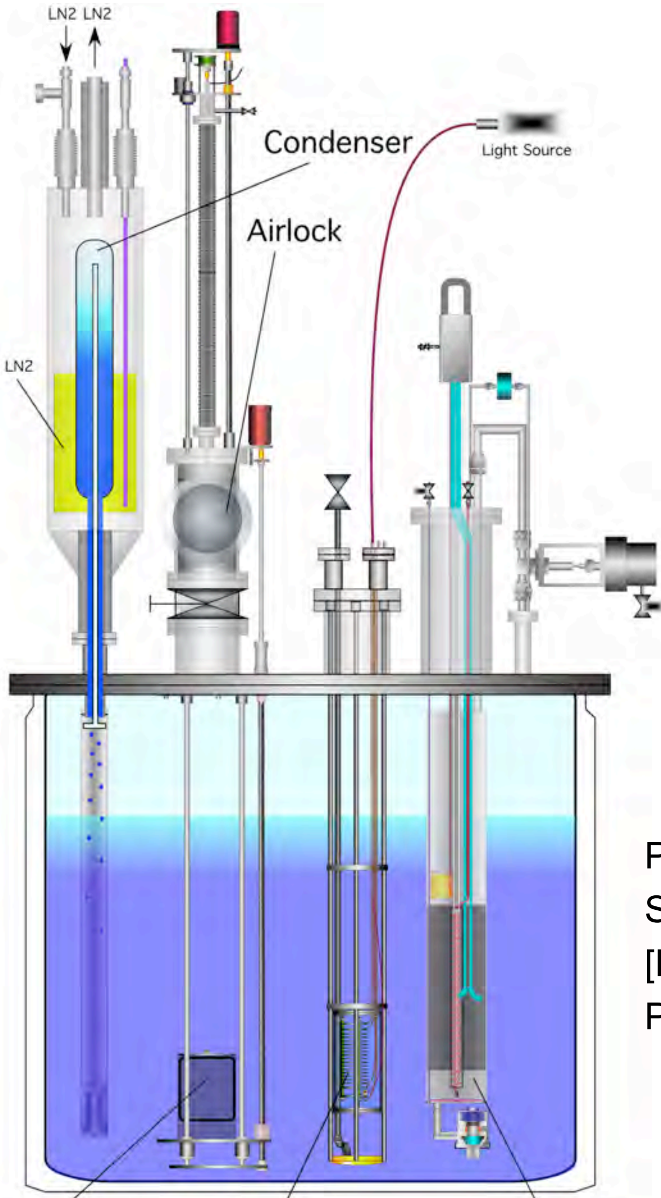
Drift lifetime Measurement



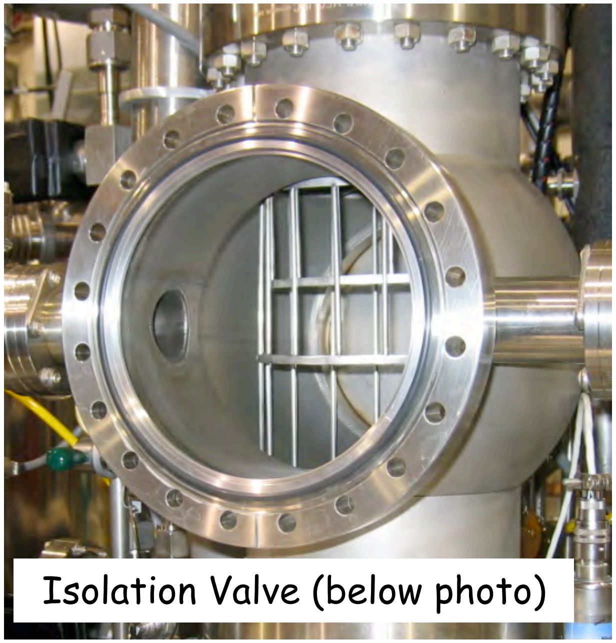
G. Carugno, NIM A 292 (1990)



Luke (Materials Test System)



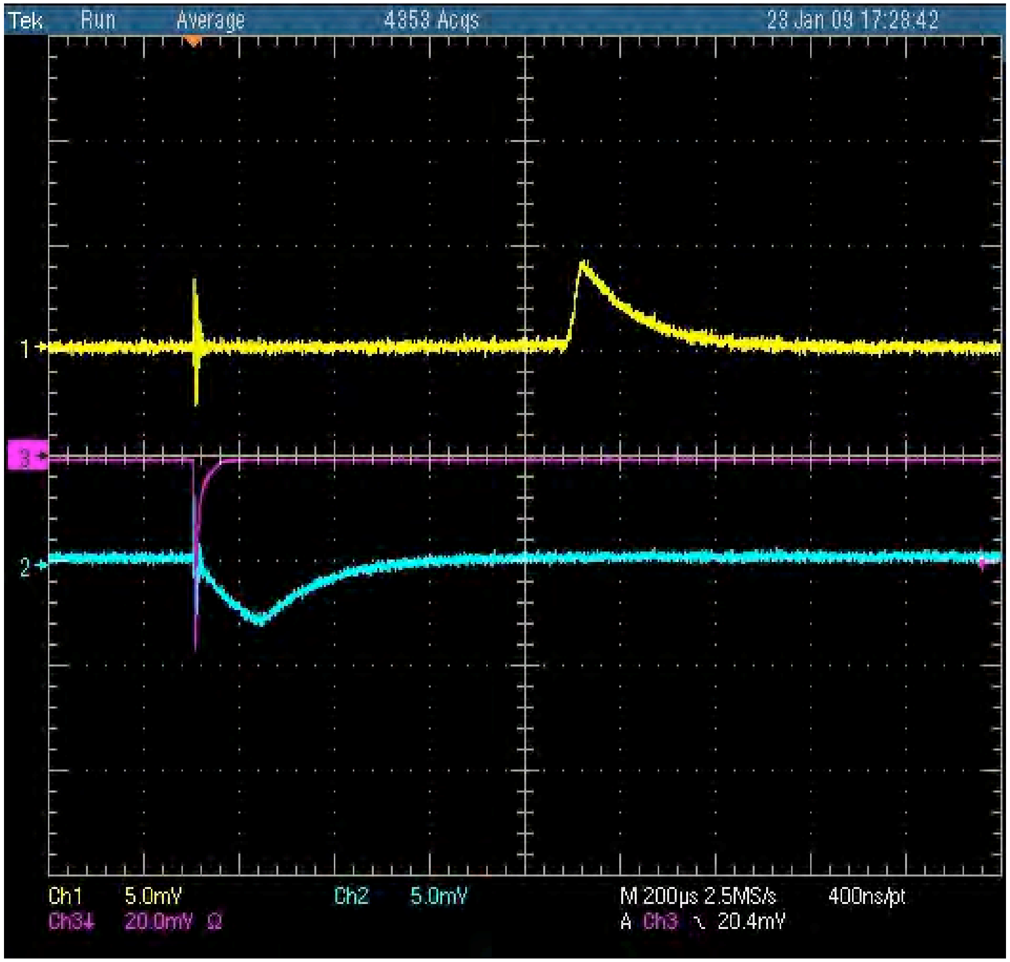
insertion of materials
without exposure to vacuum

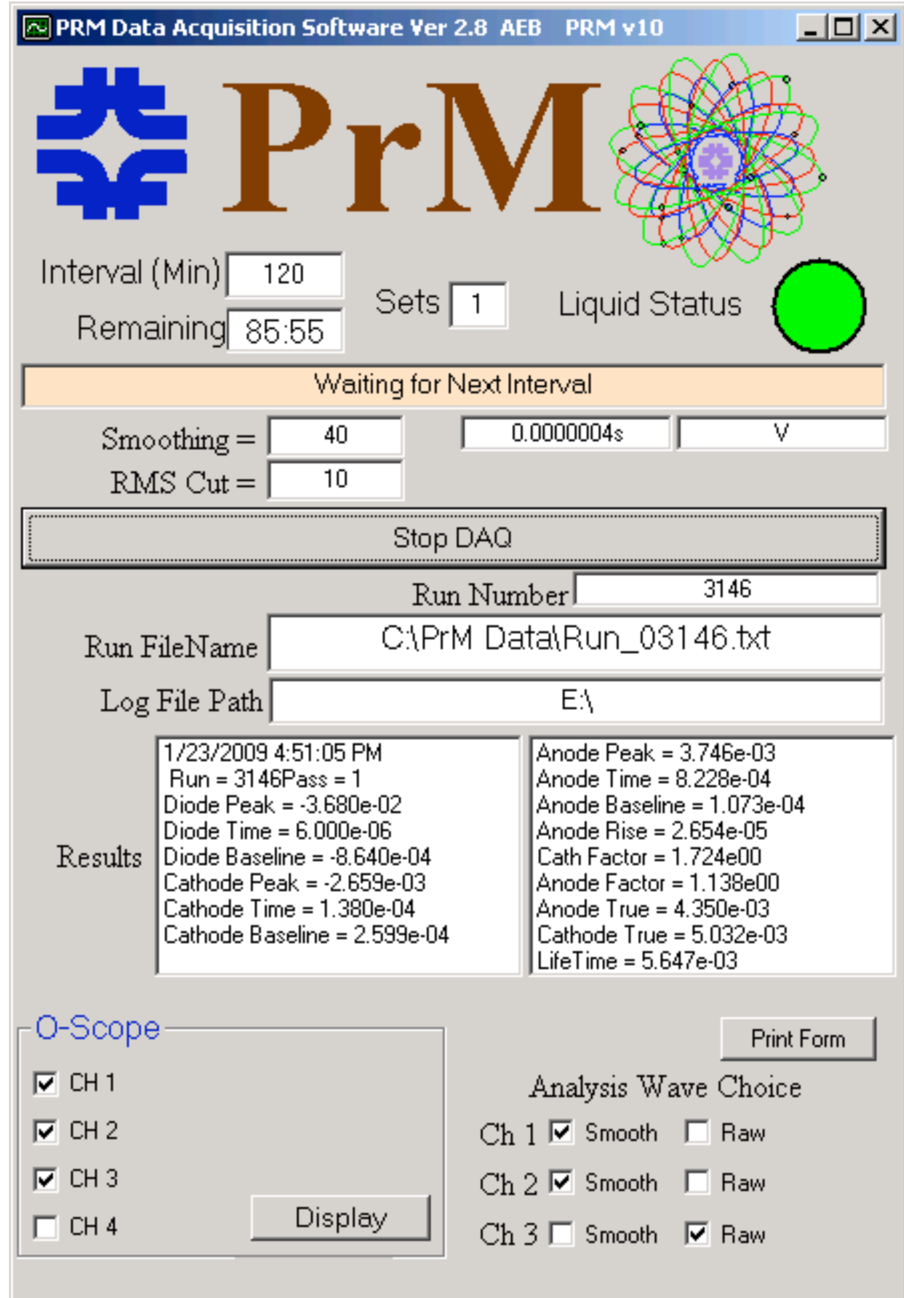


Isolation Valve (below photo)

Put materials in Sample Cage in the Argon Lock
Seal the Argon Lock (open in photograph).
[Evacuate the Argon Lock (or not).]
Purge with pure argon gas (available from the cryostat).

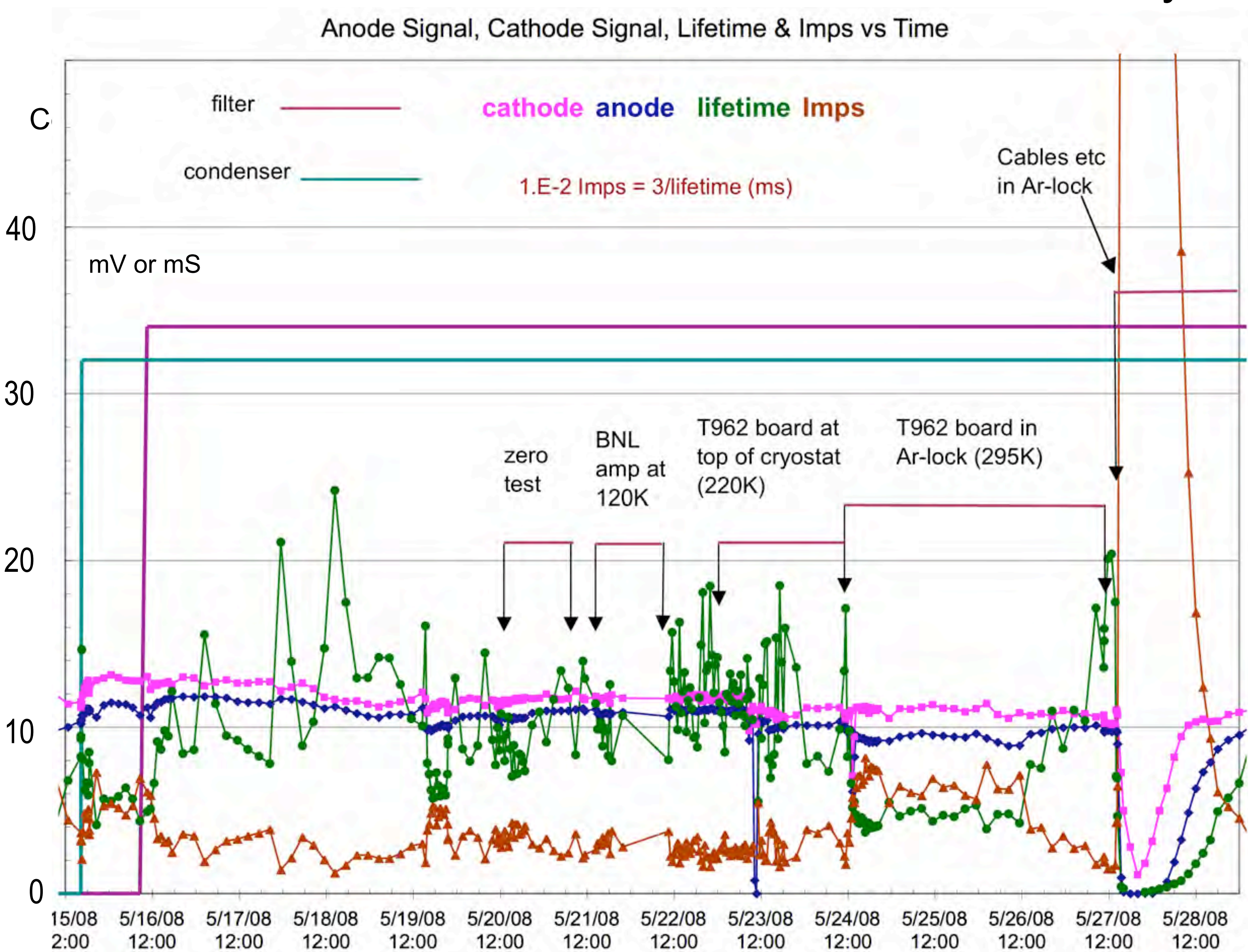
On-line data and DAQ

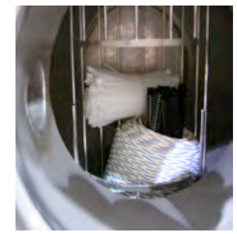


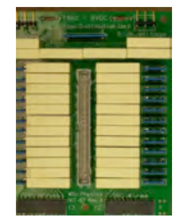


A. Baumbaugh

Some Measurements with the Materials Test System

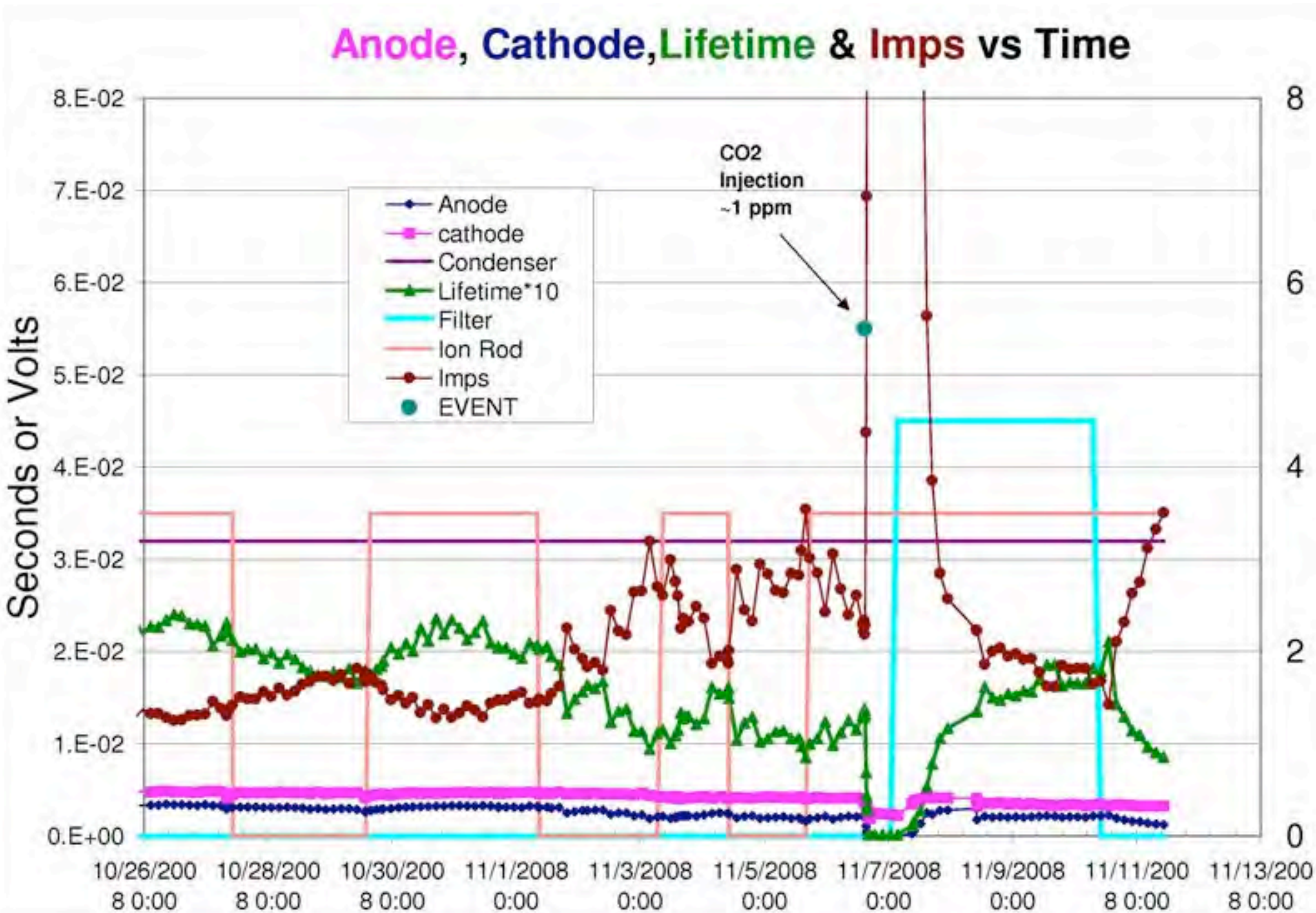



Cables and Ties


T962 Bias Card


BNL Amp

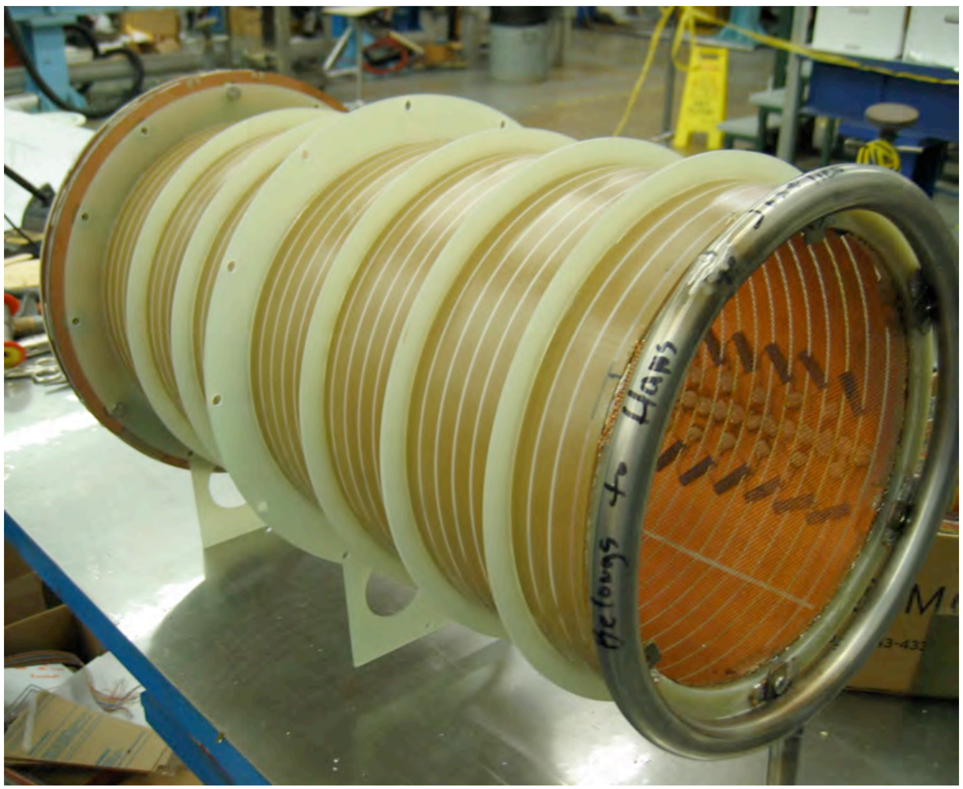
The ion-rod and a contaminant injection

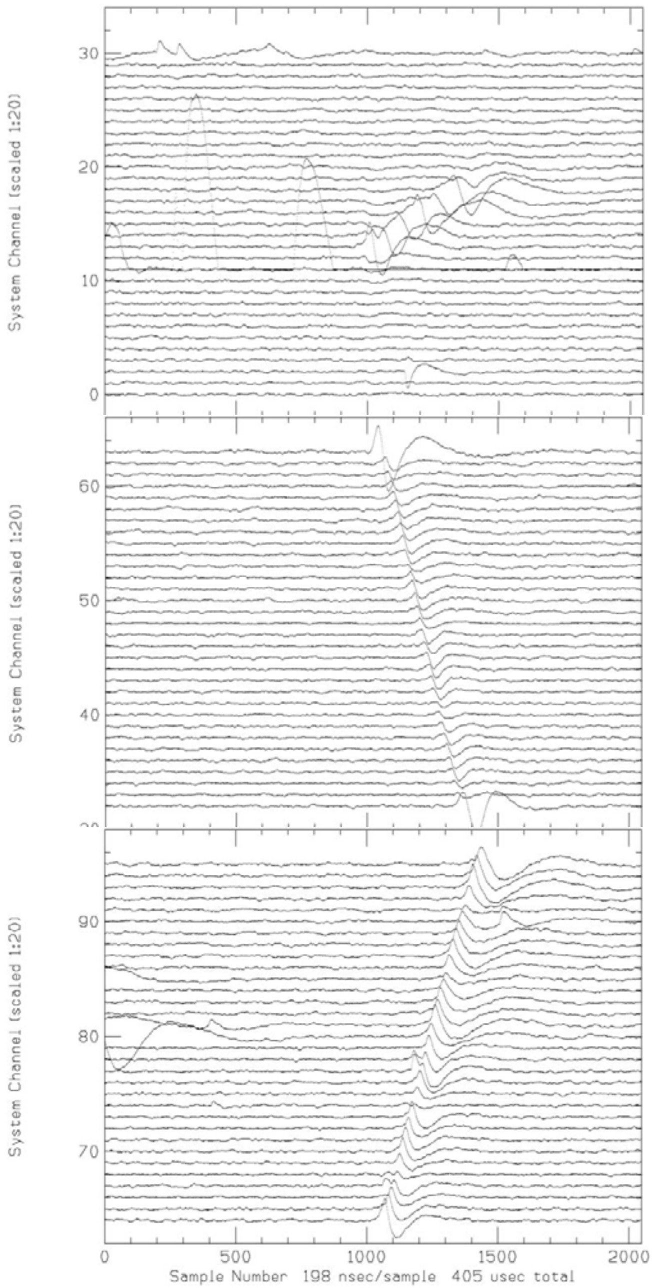


TPC (96 channels, 50 cm) for electronics development

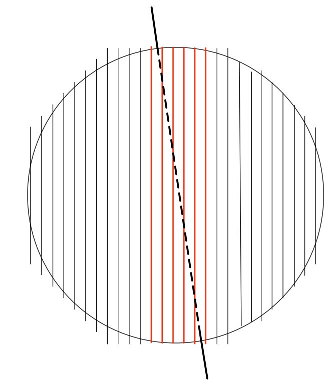
into Bo

on bench

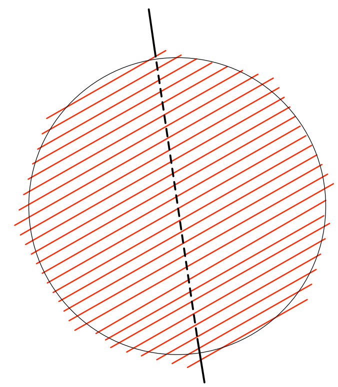




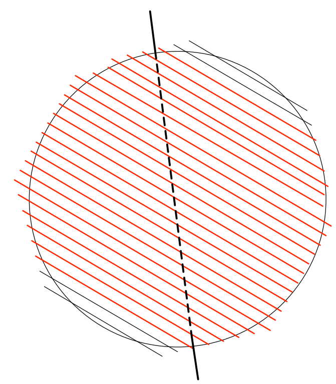
5th trigger



Plane 1
(Induction, 0°)

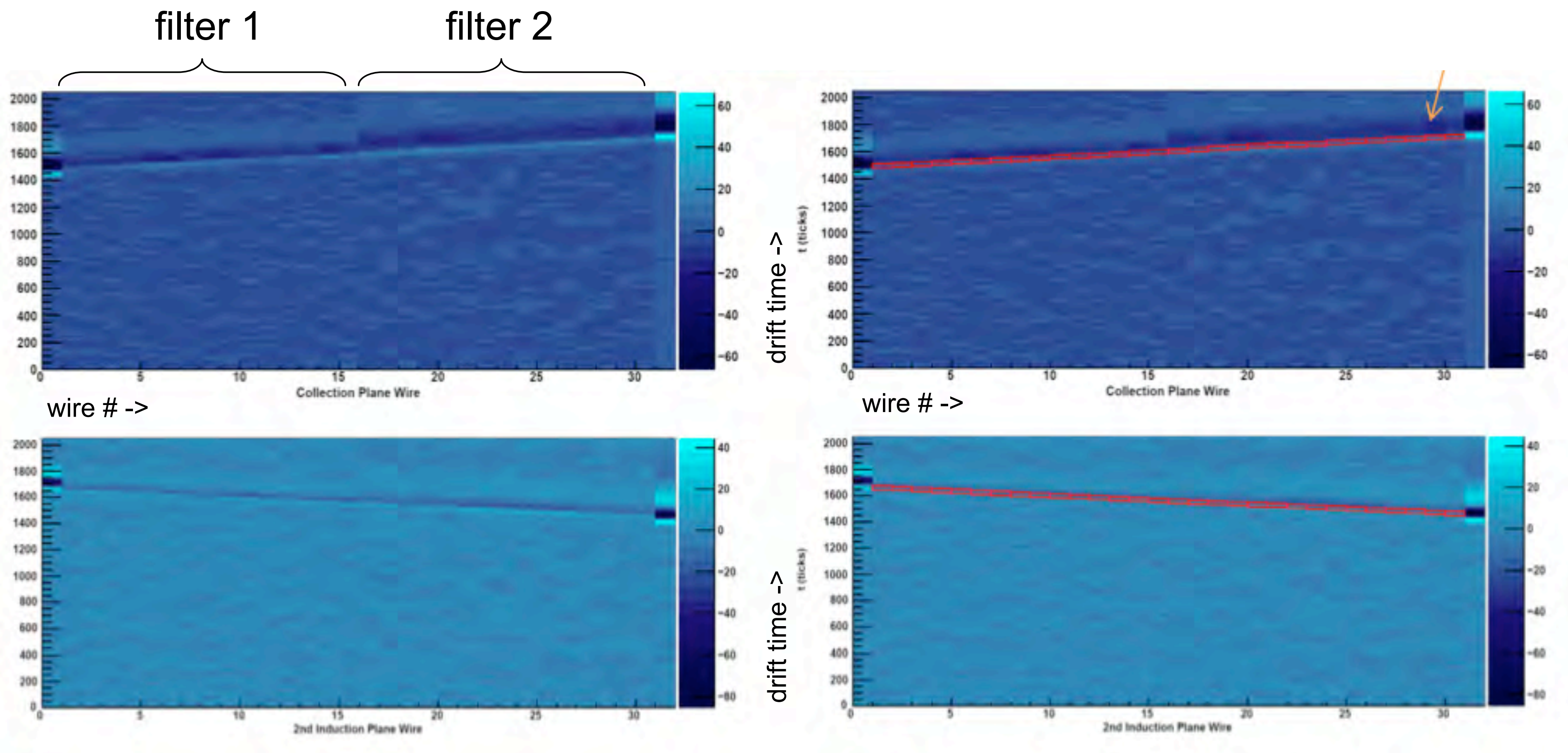


Plane 2
(Induction, +60°)



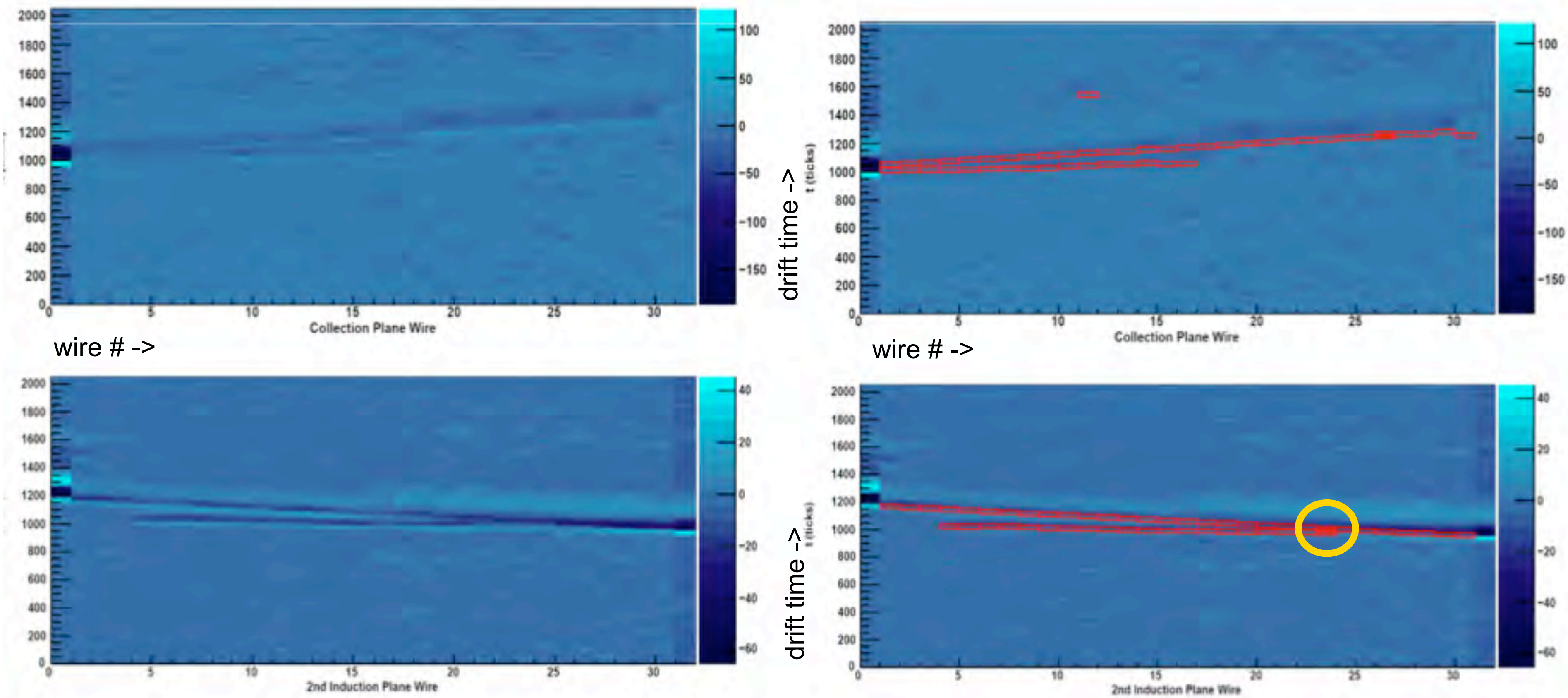
Plane 3
(Collection, –60°)

Bo Data - hit and track finding



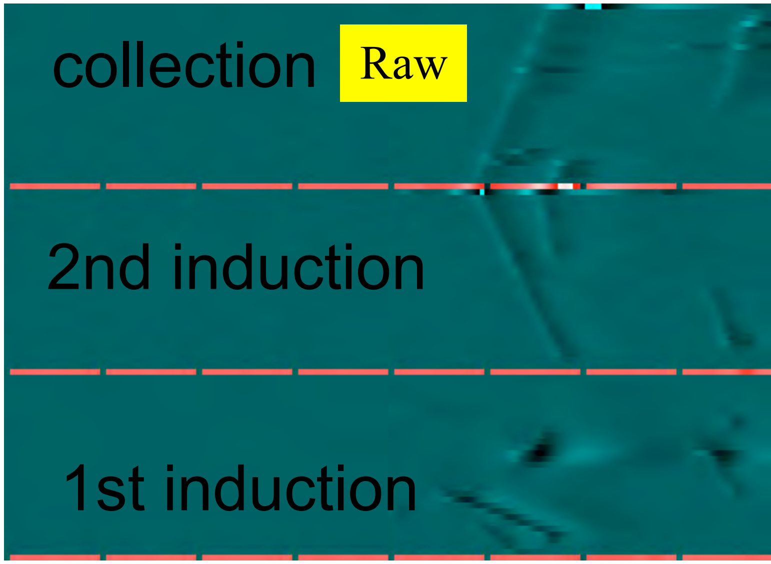
(J. Spitz, Yale)

Bo Data - two track resolution



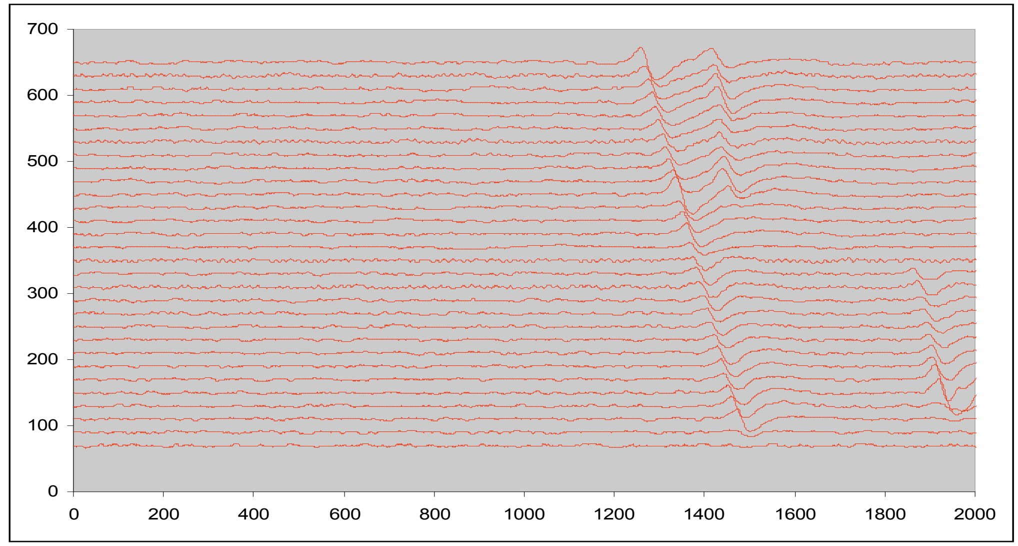
(J. Spitz, Yale)

Bo Data - signal processing (J-Y Wu)
data compaction is a major issue



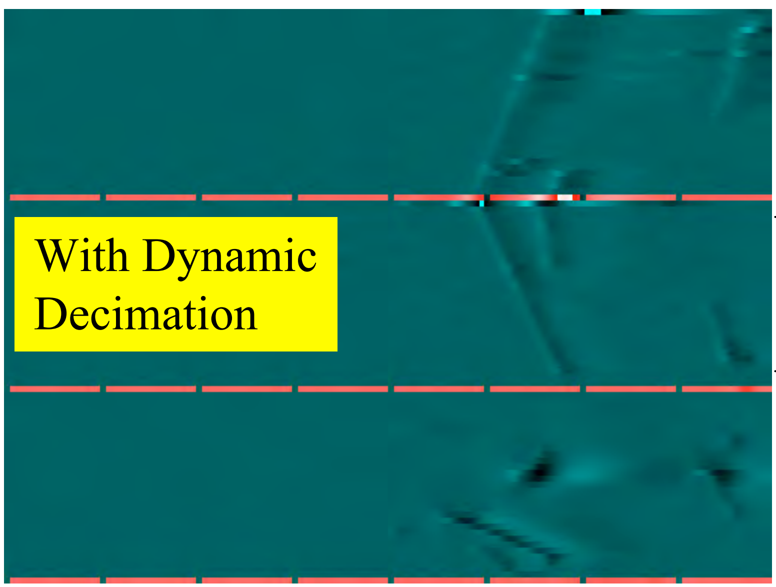
wire # ->

drift time ->

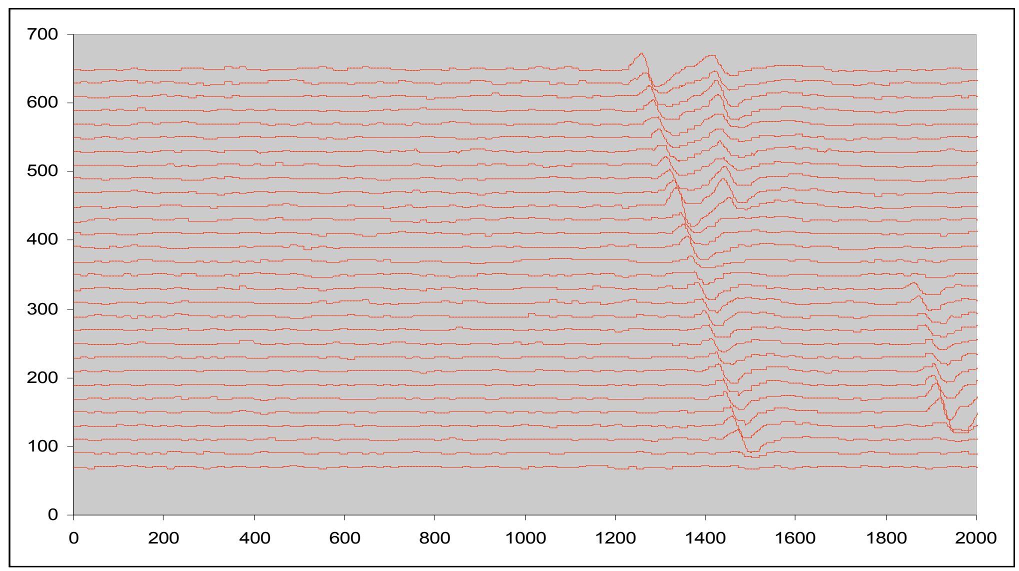


wire ->

drift time ->

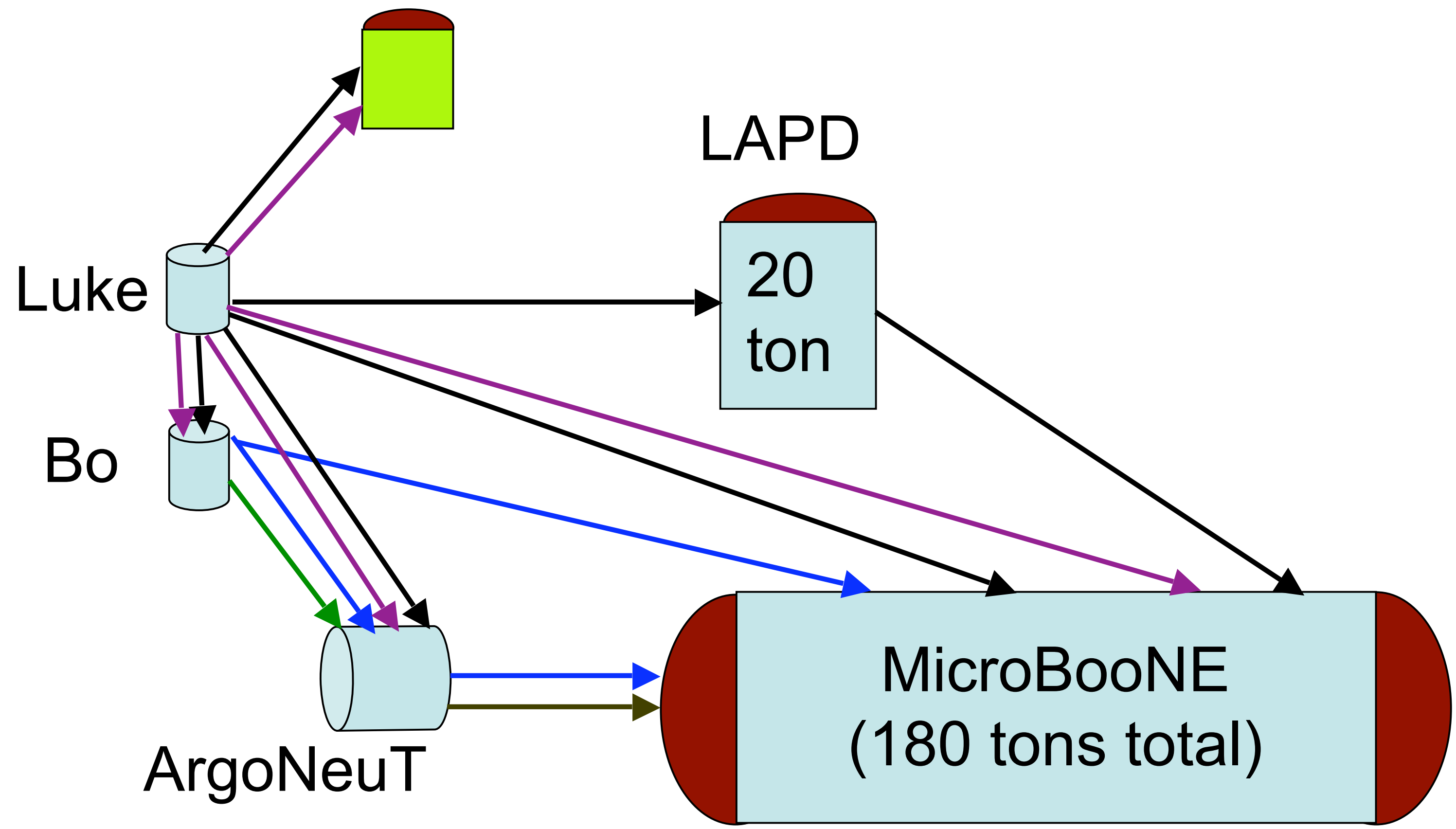


wire # ->



wire ->

Connections between various devices



- argon and purity monitoring
- materials
- electronics
- controls,software & firmware
- physics analysis

Work List for PAB devices for coming year:

Cryogenics :

General: LN2 source improvements

Luke: implement gas filtration system
install internal camera
implement/commission trace O2 and H20 instrumentation
design/build condensed liquid retention for analysis
change lines in condenser return (Lazy Suzanne)

Bo: implement closed system (filter plus condenser)

Operations: run materials tests (backlog incl. FR-4, cables, connectors)
take Bo data (interest in pulse-shapes afo angle to wire-plane)

Estimate (incl Safety Analysis/Report):

5 months Eng; 4 months MT, 1 month ET, 1 month EP; $120k M & S

Work List for PAB devices for coming year:
(Purity Demonstration instrumentation separate)

Instrumentation:

- Complete long PrM
- Develop PrM electronics to operate in liquid argon
- Test UV LEDs as alternate light source for PrM
- Develop TPC modifications to take pre-amps inside cryostat
- Extend scintillator trigger for Bo (x 2)

Electronics:

- Develop firmware (dynamic decimation, hit region finding) in Bo readout
- Develop and test `in-cryostat-electronics' for Bo

Estimate: 9 months Eng. (incl. MSU), 3 months EP, 2 months MT; $50k + MSU

What projects are missing from discussion?

Have not discussed MicroBooNE:
It has stage 1 approval and I assume it will arrange/compete for its resources.

Have not discussed LAr5:
This is a concern. In particular, the cryostat and TPC design are probably not scalable from MicroBooNE.The 20 ton Purity Demonstration vessel may be a reasonable place to test new TPC designs.
The development of appropriate in-cryostat electronics is part of the MicroBooNE program - this would benefit from the ASIC group here collaborating with BNL.